26 October 1967

MEMORANDUM FOR THE RECORD

SUBJECT: Sine Wave Test Equipment

The purpose of this memo is to briefly discuss some of the problems encountered in the use of the Sine Wave Test Equipment. A more thorough report will be submitted later if required.

There are two basic categories of problems with the equipment: those which are fairly easy to correct and those for which solutions are not obvious, if they exist at all. It is with this latter category that this memorandum is concerned. The problems of this second category are 1) the visibility threshold of the human eye, 2) the use of square wave targets in measuring modulation transfer function, 3) polarization of the object intensity distribution and 4) operator fatigue.

1) <u>The Visibility Threshold of the Human Eye</u>

The intensity distribution seen by the operator (if a sine wave object is assumed) can be expressed as

$$I(x) = K(1 + m \sin \omega y) \, [1 - M\tau_a(\omega) \sin \omega y]$$

Where m = mask modulation

M = target modulation

$\tau_a(\omega)$ = Transfer Function of lens under test

K = Constant

ω = spatial frequency

If visibility is expressed in the form

$$V(x) = \frac{I(x) - I(x + \pi/\omega)}{I(x) + I(x + \pi/\omega)}$$

or

$$V(x) = [m - M\tau_a(\omega)] \sin \omega x \, / \, [1 - mM\tau_a(\omega) \sin^2 \omega x]$$

then at null, $m - M\tau(\omega) = m/M$

where $\tau_m(\omega)$ = measured Transfer Function.

If $V(x) = V$ = Visibility Threshold of the eye, we have

$$\pm V \approx m(1 = \tau_a/\tau_m) \sin \omega x$$

letting $\omega x = \pi/2$, then

$$\pm V = m(1 - \tau_a/\tau_m)$$

or

$$\tau_a/\tau_m = 1 \pm V/m$$

The equipment as supplied has a value of m ranging from 0.1 to 0.2. The value of V for the eye is approximately .02, so for the best case, τ_a/τ_m is between .9 and 1.1. Now if m is decreased, the range of τ_a/τ_m increases; if m is increased, the range decreases. However, m is also the lowest value of MTF which can be measured using the equipment; therefore, the lowest value of τ_m which can be measured is increased. A further problem with increasing m is that it effects the visibility of the harmonics when square wave targets are used.

2) The Use of Square Wave Targets

Preliminary calculations show that when using square wave targets at frequencies where the harmonics are present in the image both the range and the average value of τ_a/τ_m change. The exact value of this change is difficult to calculate since both harmonic content and visibility threshold of the eye effect the solution. Some computer time will be necessary to evaluate these considerations thoroughly.

3) Polarization of the Object

It is noted that the object-plane is polarized and that it is possible to cause extinction in the bars or the background for differing analyzer angles. Exactly what effect this has is also difficult to analyze; however, the presence of colored fringes which have been observed in the image may be attributable to such polarization and this might also lead to erroneous results.

4) Operator Fatigue

Everyone who has operated the instrument at this facility has

complained of how hard it is on the eyes. The upper limit seems to be about 40 or 50 readings before the eye fatigues to a point where the operator must stop for several hours, possibly the rest of the day. It is not known if this strain can permanently effect the eye but such a possibility should be considered. The upper limit on number of readings would seem to be in the order of about 100 per day per individual.

The significance of these problems is more than their individual effect; it is their combined effect. The first suggests that there is an equal probability of choosing any value between certain limits, thus a large number of readings are necessary to establish an average value on which any confidence can be placed. The second suggests that the response of the lens at the harmonic frequencies must be considered where such harmonics are present, thus, the error terms may add. The fourth problem would restrict the number of readings which could be made in a day. From these three considerations alone the process of making an MTF measurement of a single lens becomes very time consuming and the results may still be in error by some undetermined amount. This in turn is coupled with a possible built-in error due to polarization. If such an error is present it is probably related in a rather complex fashion to object modulation and mechanical strain on various elements of both the test equipment and the lens under test.

Two problems which have not been mentioned since they seem to be of the variety which can be overcome given sufficient time are 1) Variations between different data sets by the same operator under where the only variation is defocussing and refocussing to apparent best focus and 2) Variations between different operators with the same variable as 1.

Variations for an individual operator between runs was found to be up to ±16% even though extreme care was used in focussing a particular lens. Variations between different operators ran as much as ±62.5%. It may be possible that each operator be calibrated and, that enough repetitions be performed, so that these errors may be removed. However, in view of all the other difficulties, it does not seem to be worth the effort.

STATINTL

FROM EDL DATE 30 Oct 67 #0

	Initial	Date
	~~[illegible]~~	2 Nov
	~~[illegible]~~ HHE	6 NOV

STATINTL

Comment: — Do you and Homer agree with his findings?

Yes! – HHE

yes RLS

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